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Himalayan snow chemistry: Chemical composition of fresh snow samples from Kashmir valley

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ABSTRACT

The present paper deals with variability in snow chemistry of various sites spread in six districts of the Kashmir Himalayan valley, experiencing frequent snow fall during winter (Dec.- Feb). Chemical composition of fresh snow samples shows wide changes in pH (5.8–7.3), dissolved oxygen content (22-26 mg L^{-1}), and total alkalinity (2-3 mg L^{-1}). The levels (mg L^{-1}) of calcium (13.3– 28), magnesium (8-12), chloride (15-30), sulphate (2-8), silicate (1-4) and nitrate (1.9-3.9) differed considerably. The study makes a strong plea for in-depth investigations of snow chemistry of little-explored Himalayan region, useful for assessing the impact of environmental pollution.

Key words: Chemistry, Major ionic composition, Fresh -snow, Site-variability, Kashmir Himalaya.

INTRODUCTION

Various attempts have been made (,Reynolds, 1983, Jenkins *et al* 1987; Gunz and Hoffman, 1990; Marinoni *et al*, 2001; Toom-Sauntry and Barrie, 2002; Rohrbough *et al* 2003; Walker *et al* 2003 Kang *et al* 2005) to document the chemical composition of snow in different parts of the world. However, except for sporadic studies (,Naik *et al* 1995; Sarfaraz *et al* 2001; Lone and Khan 2007) research on snow chemistry of mountain- clad Kashmir Himalayan valley has been ignored. In order to remedy this deficiency in environmental chemistry of the region, an attempt has been made to analyze the hydrochemistry of fresh snow samples collected from various sites spread in six districts of Kashmir valley.

MATERIALS AND METHODS

Sampling sites

The Kashmir valley of Jammu and Kashmir State is situated between 32^0 17' - 37^0 15' N and 72^0 40' - 80^0 30' E and occupies a strategic position in the north of India. Srinagar city, the summer capital of J&K State is located at an average altitude of 1500-1600 m asl and its atmosphere receives inputs mainly from automobiles and small - scale industries.The three sampling sites viz Lal Chowk, HMT area and Shalimar were selected in the district Srinagar. Whereas, the atmosphere of former two sites remains polluted with automobile emissions and the operation of small-scale industrial units, the other one is relatively a non-polluted area. The other sampling sites viz; Rafiabad, Dragmulla, Tral, Magam and Anantnag spread in various parts of Kashmir valley are located in district Baramulla, Kupwatra, Pulwama, Budgam and Anantnag respectively.

The winter season in Kashmir valley extends from Dec- Feb and is marked by cloudy and cold weather. On an average 7-8 winter disturbances pass east- wards in winter months affecting the northern most part of India. These disturbances are accompanied by continuous rain and appreciably low temperature, helping the formation of snow and ice in these regions *(Naik et al, 1995*) and approximately 50% of these affect the region covering Jammu and Kashmir, Himachal

Pradesh, Haryana and the hills of western Uttar Pradesh and Uttranchal. The snowfall recorded at Agrometerological Observatory Shalimar (SKUAST-K) Kashmir during the winter of December, 2004 and Feb. 2005 is given in Table 1.

Table -1: Snowfall recorded at Agro-meteorological Observatory SKUAST-K, Shalimar

Snow fall	Dec.2004	Jan. 2005				Feb.2005						
	28	21	22	23	3	7	6	18	19	20	21	24
Perday	8	2.6	22.8	2.8	2.8	20	33.2	14.4	89	57	8.5	2
Total	8	28.2	224.9									

Source: Division of Agronomy, SKUAST-K, Shalimar

Sampling procedure and Analytical Methods

The fresh snow samples were collected from various sampling sites on the dates shown in Table 2. The snow samples were collected with a glass cylinder 40 cm long and 5 cm diameter.

Table - 2: Date of collection of fresh snow samples from variou sites of Kashmir

Site / District	Date of Sampling
Lal Chowk/ Srinagar	28.01.2005
HMT/ Srinagar	25.01.2005
Shalimar / Srinagar	24.01.2005
Rafiabad/ Baramullah	22.01.2005
Dragmulla/ Kupwara	06.02.2005
Tral/ Pulwama	08.02.2005
Magam/ Budgam	25.01.2005
Anantnag	02.02.2005

Each sample was melted in the plastic tub covered with a glass sheet pre-cleaned with deionized water and allowed to reach ambient room temperature. After melting, the snow water was transferred into a 1 liter capacity polythene bottles which was sealed and returned to the laboratory for analysis.

The pH of the snow- melt was measured immediately by using electronic digital pH meter (Systronics 327). Methods recommended by Mackereth (1963*)* and the American Public Health Association (1992) were used for various physical and chemical variables. The Cl content was determined tritrimatrically against $AgNO_3$ and total alkalinity was estimated against standard solution of H_2SO. Dissolved oxygen (DO) was determined by Winkler's reagent and titrated against standard solution of $Na_2S_20_3$,. Nitrate-nitrogen was estimated spectrophotometrically following phenol- disulphonic acid method, while sulphate was determined by the turbidimetric method. Silicate content was also determined colorimetrically by using acid-molybdate solution. Analysis of cations (Ca and Mg) was done titrametrically using Na_2EDTA (disodium dihydrogen ethylene diamine-tetraacetate).

RESULTS AND DISCUSSION

The average concentration of pH and dissolved oxygen content, and major ionic forms of the snow samples collected from different sites of Kashmir valley are given in Table 3. The data indicate that the pH of the snow samples was the lowest (5.84) in HMT area of Srinagar city ,and for other sites pH values ranged from 6.2 (Anantnag) to 7.31 (Shalimar). The reference level commonly used to compare acid precipitation to natural precipitation is pH 5.6, the pH that results from the equilibration of CO_2 with precipitation. This reference level has been chosen because of the ubiquity of CO_2 in the global atmosphere and because of the absence of data on other acids or basics (Naik *et al* 1995).However, Galloway *et al* (1982) believe that there is no single natural pH of precipitation applicable to the whole globe, but rather several natural values, each unique to a region, the size of a continent or an ocean. The lowest values for pH in the snow samples of the HMT area could be attributed to the presence of higher concentration of species like NO_3 and SO_4 in the atmosphere of this region due to the operation of small- scale

Table - 3: Data on important chemical variables of fresh snow samples, Kashmir *(Except for pH, all values in mg L^{-1}).*

Site/ District	pH	Diss.Oxy.	Tot.Alk	Ca	Mg	Cl	SO_4	NO_3	SiO_3
Lal Chowk/ Sgr.	6.59	24	2.9	28	16.5	28	5.5	1.9	4
HMT/ Sgr.	5.84	24	2.0	12	8	25	8	3.9	3
Shalimar/ Sgr.	7.31	24	3.0	20	10.2	30	5	2.3	2
Rafiabad/B'mula	6.74	26	2.5	16	10	20	4.5	1.9	1.9
Dragmulla/ Kup.	6.74	24	2.0	16	11	25	4.5	2	2
Tral/ Pul.	6.79	26	3.0	20	12	22	2	2	0.5
Magam/ Bud.	6.39	24	2.5	16	12	19	4	1.9	1
Anantnag	6.20	22	2.5	13	11	15	3	2.8	2

industrial units involving burning of coal, oil and timber.

The chloride content and total alkalinity in the snow samples ranged from 15-28 and 2.-3 mg L^{-1} respectively in different zones of Kashmir valley and suggest a strong influence of alkaline dust particles which might have originated from Indian plains and arid zones in the west and have been transported to the region by south westerly, winds (Naik *et al* 1995). The data also indicate that dissolved oxygen content in the snow samples collected from different sites of Kashmir valley ranged from 22-24 mg L^{-1} and suggests a fairly good concentration of O_2 in the atmosphere.

High concentration of NO_3 (3.9 mg L^{-1}) and SO_4 (8 mg L^{-1}) were recorded in the HMT area compared to other sites. Since SO_2 and NO_2 are mainly derived from anthropogenic sources, the high levels of these species in the snow samples of HMT area are likely to be due to industrial activity in the area. The other sites (e.g. Lal Chowk) has significantly higher traffic-flow with appreciably higher NO_x concentration in the atmosphere. However, during night time, the traffic usually remains off the road and consequently snow recorded lesser concentration of these species as the snowfall was recorded during the night hours. Under natural conditions, nitrate particles of submicron size in the atmosphere may be formed by gas to particle conversion process *(*Cox*,* 1974*).* Under normal atmospheric conditions, HNO_3 can initially form Aitken nuclei which will grow rapidly into a submicron sizes and react with NH_4 to NH_4NO_3. This reaction is reversible and temperature dependent (Wolff, 1984). The formation of NH_4NO_3 in tropical countries is rare due to persistence of higher temperature. However, HNO_3 can react with soil derived or some industrial particulates and become incorporated in snow as the coarse aerosol mode (Wolff, 1984). It is also clear from the data that the other sites(viz. Shalimar, Rafiabad, Tral, Magam and Anantnag) have almost negligible traffic-flow and consequently low concentrations of the NO_3 and SO_4 were observed during the present study.

The data also reveal that HMT site recorded low content of Ca^2 (12 mg L^{-1})and Mg (8 mg L^{-1}) . However, highest values were observed in Lal Chowk area (Ca=28.05 and Mg= 16.5 mg L^{-1}) .For other sites (Table 3), the values differed markedly; Anantnag (Ca=13 mg L^{-1}) and Shalimar/ Tral (Ca=20 mg L-1). The Magnesium content fluctuated narrowly between 10-12 mg L-1 for the sites. The influence of alkaline components on the pH of the rain, cloud and fog water in India has been reported earlier (Khemani *et al* 1987). The higher concentration of alkaline components (Ca and Mg) are responsible for the higher pH of precipitation in India and the alkaline pH in the snow samples collected from Lal Chowk, Shalimar, Rafiabad, Dragmulla, Tral, Magam and

Anantnag is consistent with these observations. The presence of appreciably higher concentration of Ca has also been reported in the snow samples of Mt. Everest by Marinoni *et al* (2001). Other related studies have also shown higher ionic concentration of Ca in the premonsoon snow and have opined that it may be as a result of dust deposition during the peak dust storm activity mainly in April and May over Asia (Parrington *et al*, 1983). On the other hand, relatively low concentration of Ca and Mg in the snow samples collected from HMT area may also be one of the factors responsible for its low pH value.

Conclusion

Analytical research on ionic composition of fresh snow is a useful tool for assessing the environmental impact of air pollution sources as well as the transport and deposition of various air pollutants. The study has indicated the presence of highly appreciable concentration of anions (Cl) total alkalinity, $MgSO_4$ and SiO_3 as well as cations (Ca and Mg) in the fresh snow samples collected from different areas of Kashmir valley., The presence of these ions seems directly related to site-specific environmental conditions of the Himalayan region.

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